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(54) HIGH VOLTAGE CIRCUIT INTERRUPTER

(71) We, WESTINGHOUSE ELECTRIC CORPORATION, of Three Gateway Center, Pittsburgh 30, Pennsylvania, United States of America, a corporation organized and existing under the laws of the Commonwealth of Pennsylvania, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to high voltage circuit interrupters and more particularly, to high voltage fuse structures. The invention disclosed in the present application involves the use of the inventions disclosed and claimed in the following co-pending patent applications 32229/68 (Serial No. 1200702), 32836/68 (Serial No. 1200704), 32835/68 (Serial No. 1200703), 33636/68 (Serial No. 1200705) and 34071/68 (Serial No. 1200706).

The principal object of this invention is to provide a high voltage power fuse construction of the dual-bore type which includes means for limiting the gas pressure occurring when the power fuse is called upon to interrupt relatively high currents.

With this object in view, the present invention resides in a circuit interrupter comprising a tubular electrically insulating casing, a body of gas evolving, arc-extinguishing material disposed inside of and spaced from the ends of the casing, said body of arc-extinguishing material including a plurality of generally cylindrical blocks stacked axially in end-to-end relation, each of said blocks having a relatively large opening and a relatively small opening extending axially therethrough with the large openings and the small openings, respectively, being substantially aligned, separate conducting means disposed both in the small openings for interruption of first current arcs and in the large openings for interruption of second current arcs said conducting means being connected to separate fusible means disposed inside the casing adjacent to one end of the body of arc-extinguishing material, at least the block adjacent to said fusible means having a recess formed therein spaced laterally from the large opening and extending around the large opening with the ends of the recess being adjacent to and spaced from the small opening, a wall portion of said block surrounding the large opening being sufficiently thin to break under the influence of intense heat and pressure to thereby increase the volume of the large opening through the associated block.

The invention will become more readily apparent from the following description of a preferred embodiment thereof shown, by way of example only, in the accompanying drawings, in which:

Figure 1 is a side elevational view of a high voltage power fuse structure which embodies the principles of the present invention and which is shown vertically mounted in the normally closed operating condition;

Fig. 2 is an enlarged, longitudinal, sectional view of a fuse unit which forms part of the fuse structure shown in Fig. 1 with portions of the end fittings of the fuse unit omitted;

Fig. 3 is an enlarged top plan view of a generally annular block of gas evolving material which forms part of a body of arc-extinguishing material which is incorporated in the fuse unit of Fig. 2;

Fig. 4 is an enlarged side elevational view of the block of gas evolving material shown in Fig. 3;

Fig. 5 is an enlarged, partial, side elevational view of an alternative construction for a portion of the fuse unit shown in Fig. 2;

Fig. 6 is an enlarged top plan view of a generally annular block of gas evolving material which forms part of the alternative fuse unit construction shown in Fig. 5; and

Fig. 7 is an enlarged side elevational view of the block of gas evolving material which is shown in Fig. 6.

As illustrated in Fig. 1, the fuse structure 10 includes a base (not shown) formed of sheet metal and a pair of outwardly extending insu-

lator supports 272 and 282. The upper insulator support 272 fixedly supports in position a latching assembly 250 which includes a relatively stationary break contact 252. The lower insulator support 282 supports a hinge assembly 260 which, in turn, pivotally supports a fuse unit 100 and which includes a relatively stationary hinge contact 262. As illustrated in Fig. 1, the fuse unit 100 serves to electrically bridge the upper break contact 252 and the lower hinge contact 262 so that electric current will normally pass therebetween by way of terminal pads (not shown) to which an external electrical circuit may be connected.

The fuse unit 100 includes a generally tubular fuse holder or casing 32 which is formed from a suitable weatherproof, electrically insulating material, such as a glass fiber reinforced epoxy resin or the like, and a pair of upper and lower end fittings or terminals 34 and 36, respectively, which are disposed at the opposite ends of the holder 32 and which are formed from an electrically conducting material. The upper and lower end fittings or terminals 34 and 36, respectively, are securely fastened to the opposite ends of the associated holder or tube 32 by suitable means, such as cement, and a plurality of pins (not shown) which pass transversely through both the end fittings 34 and 36 and the associated holder 32. As illustrated, the fuse unit 100 also includes a hook eye 274 which is pivotally mounted on a laterally projecting portion 34A of the upper end fitting 34, as shown in Fig. 2, and which may be utilized for effecting opening and closing movements of the fuse unit 100 by means of a conventional hook-stick. The lower end fitting 36 includes a hinge lifting eye 284 which may be formed integrally with the lower end fitting 36 and which may be employed in conjunction with a conventional hook-stick to effect physical removal of the fuse unit 100 from the hinge assembly 260 for replacement or insertion of the fuse unit 100. The lower end fitting or terminal 36 also includes an inwardly projecting flange portion 36B against which the lower end of the holder or casing 32 bears, as shown in Fig. 2.

The fuse unit 100 further includes a renewable or refillable unit 20 which is mounted or disposed within the holder structure which includes the outer tube 32 and the upper and lower end fittings or terminals 34 and 36, respectively. The renewable unit 100 includes its own supporting tube or insulating casing 110 which is formed from a suitable electrically insulating material having sufficient strength to withstand the internal gas pressures and intense heat which result during an interrupting operation of the fuse unit 100, such as a glass fiber reinforced epoxy resin. A body of gas evolving, arc-extinguishing material, such as boric acid, is disposed inside the tube or casing 110 and axially spaced from the ends thereof. The body of gas evolving material may include a plurality of generally annular blocks 122, 124, 126 and 128, each of which includes a relatively larger central opening as indicated at 125 for the block 128 in Fig. 3 and a relatively smaller opening at one side thereof, as indicated at 127 for the block 128 in Fig. 3, both of the openings in each block extending axially through the respective blocks. When the blocks 122, 124, 126 and 128 are axially stacked in end-to-end relation as shown in Fig. 2, with the respective larger and smaller openings thereof substantially aligned, a main bore 130 is formed through the body of gas evolving, arc-extinguishing material which includes said blocks and a relatively smaller auxiliary bore 192 is formed through a body of gas evolving, arc-extinguishing material.

In order to prevent the travel of ionized gases between the main bore 130 and the auxiliary bore 192 during an interrupting operation of the fuse unit 100, the meeting surfaces of the blocks 122, 124, 126 and 128 are structurally joined to one another around the relatively smaller openings which form the auxiliary bore 192 by a sealing and bonding material having a relatively high dielectric strength, such as an epoxy resin. More specifically, the meeting surfaces of the blocks 122, 124, 126 and 128 each includes a recess or groove as indicated at 128B in Fig. 3 for the block 128 which extends substantially around the relatively smaller opening in each of said blocks and forms with the adjacent block a combined passageway which is substantially filled with the sealing and bonding material, as indicated at 132 in Fig. 2. It is to be noted that the manner in which the blocks 122, 124, 126 and 128 are bonded to one another around the auxiliary bore 192 substantially prevents the entrance of the sealing and bonding material into either the auxiliary bore 192 or into the main bore 130.

In order to limit the gas pressures which result during an interrupting operation of the fuse unit 100 at relatively high currents inside the tube or casing 110 to a value within the rupture strength of the casing 110, each of the blocks 126 and 128 as illustrated includes a recess as indicated at 129 which extends axially from one end of each of said blocks to an axial position or point which is axially spaced from the other end of the respective blocks, as best shown in Figs. 3 and 4 for the block 128. It is to be noted that the recess 129 of the block 128, as shown in Fig. 4, is spaced from the lower end of the block as viewed in Fig. 4 by the thickness of the gas evolving material as indicated at 128D. As shown in Fig. 3, each of the recesses 129 is laterally or radially spaced from the large opening of the associated block, as indicated at 125 in Fig. 3 for the block 128, and extends around the large opening in a generally C-shaped configuration with the peripheral ends of the recess 129 terminating short of the por-

tion of the associated block which includes the relatively smaller opening which forms part of the auxiliary bore 192.

Each of the blocks 126 and 128 includes therefore around the major portion of its periphery and outer wall, as indicated at 128E for the block 128 in Figs. 3 and 4, and a frangible inner wall, as indicated at 126A and 128A, respectively in Figs. 2, 3 and 4 for the respective blocks 126 and 128, which tends or is adapted to break up or disintegrate when the fuse unit 100 is called upon to interrupt relatively large currents and the blocks 126 and 128 are subjected to intense heat and relatively high gas pressures within the main bore 130. During such an interrupting operation, the size or volume of the main bore 130 through the blocks 126 and 128 is effectively increased by the breaking up of the inner walls 126A and 128A of the blocks 126 and 128, respectively, to thereby increase the size or volume of the gas passageway through said blocks and to limit the gas pressure which results in the main bore to a value less than that which would otherwise result. It is to be noted that the blocks 126 and 128 are assembled with the open ends of the recesses 129 facing each other and with the closed ends of the blocks 126 and 128 axially spaced away from one another as best shown in Fig. 2. By such a construction, the integrity of the main bore 130 is normally maintained through the blocks 126 and 128 when the fuse unit 100 is interrupting currents less than those which result in the breaking up of the frangible inner walls of the blocks 126 and 128 to thereby more effectively confine the arc and result in sufficient gas pressure as required to interrupt the particular magnitude of current which the fuse unit 100 is interrupting. The presence of the recesses 129 and the blocks 126 and 128 has the effect of structurally weakening the blocks 126 and 128 to permit the increase in the size or volume of the main bore 130 through said blocks during the interruption of relatively high currents, while at the same time maintaining a normal size gas passageway through the main bore 130 as it extends through the blocks 126 and 128 when the fuse unit 100 is interrupting currents which result in relatively lower gas pressures which would not be high enough to rupture the outer tube or casing 110. In summary, the breaking up of the frangible inner walls 126A and 128A of the blocks 126 and 128, respectively, when the fuse unit 100 is called upon to interrupt relatively large currents results in a sudden increase in the volume of the gas base inside the tube or casing 110 as the pieces of the frangible inner walls 126A and 128A are blown out of the lower end of the refillable unit 20 to thereby limit the gas pressure inside the tube or casing 110 to a safe value within its rupture strength.

In order to retain the blocks 122, 124, 126 and 128 in assembled relationship with the associated tube or casing 110 as shown in Fig. 2, the outer surfaces of said blocks may be coated with a suitable cement, such as an epoxy bonding material, prior to the assembly of the blocks inside the casing 110, said cement serving to bond said blocks to the casing. In addition, a generally annular retaining member or plug member 189 may be disposed at the upper end of the blocks 122, 124, 126 and 128 with the major portion of the retaining member 189 extending axially inside the casing 110 as shown in Fig. 2. The retaining member 189 may be formed or molded from a suitable electrically insulating material having sufficient strength to assist in retaining said blocks in assembled relationship with the casing 110 during an interrupting operation of the fuse unit 100, such as a glass-polyester material. A washer 183 formed from similar material may be disposed between the retaining member 189 and the uppermost block 122, as viewed in Fig. 2, and may be employed during the assembly and bonding of said blocks together prior to the assembly of said blocks inside the casing 110. It is to be noted that the retaining member 189 as well as the washer 183 includes a relatively larger central opening which forms an extension of the main bore 130 and a relatively smaller opening which forms an extension of the auxiliary bore 192. In order to assist in retaining the member 189 in assembled relation with the associated casing 110 during an interrupting operation of the fuse unit 100, the outer surface of the retaining member 189 and the inner surface of the tube or casing 110 at the upper end of said casing include adjacent helical grooves which together form a passageway in which a helical wire 181 is disposed to firmly secure the retaining member 189 in assembled relation with the casing 110. The retaining member 189 may be assembled with the upper end of the casing 110 by first assembling the helical wire 181 in the groove around the outer surface of the retaining member 189 and then screwing the retaining member 189 into the upper end of the casing 100 to the final position shown in Fig. 2.

In order to substantially prevent the escape of ionized gases from the upper end of the refillable or renewable unit 20 around the elongated conducting member 83 which extends through the main bore 130, a generally tubular member 185 is disposed in concentric or nested relation with the retaining member 189, as shown in Fig. 2, and is preferably formed from an electrically insulating material having a relatively low coefficient of friction, such as polytetrafluoroethylene which is sold under the trademark "Teflon." A shoulder portion 185A is provided at the upper end of the tubular member 185 and includes an opening of reduced cross-section or size through which the conducting member 83 passes and which forms

a substantially gas-tight seal with the conducting member 83 during an interrupting operation of the fuse unit 100 when the conducting member is actuated to move axially upwardly, as viewed in Fig. 2. The tubular member 185 also acts as a bearing to guide the axial movement of the conducting member 83. In order to prevent the tubular member 185 from being blown out of the upper end of the tube 108 during an interrupting operation of the fuse unit 100, the retaining member 189 includes an inner shoulder portion against which the upper end of the tubular member 185 bears, as shown in Fig. 2. The escape of ionized gases from the upper end of the renewable unit 20 from the auxiliary bore 192 may be adequately prevented by reducing the size of the relatively smaller opening through the retaining member 189 through which the auxiliary conductor 182 passes so that the cross-section of the auxiliary conductor 182 substantially fills the relatively smaller opening through the retaining member 189.

In order to further assist in retaining the blocks 122, 124, 126 and 128 in assembled relationship with the tube 108 during an interrupting operation of the fuse unit 100, a generally tubular or annular retaining member 142 is disposed inside the casing 110 at the lower end of the blocks 122, 124, 126 and 128, as shown in Fig. 2, and is formed or molded from an electrically insulating material having sufficient strength to assist in retaining the blocks 122 through 128 inside the casing 110 during such an interrupting operation, such as a glass-polyester material. The outer surface of the retaining member 142 is preferably coated with a suitable cement or bonding material, such as an epoxy bonding material, prior to the assembly of the retaining member 142 inside the tube 110. This bonding material serves to bond the retaining member 142 to the inside of the casing 110. The retaining member 142 includes a relatively larger opening which extends axially therethrough, as indicated at 142A, into which the lower end of the main bore 130 opens and which may serve as an exhaust passageway for high pressure gases which result during the operation of the fuse unit 100. The opening 142A also serves as a chamber in which the fusible means 160 is disposed. The retaining member 142 also includes a relatively smaller opening 142B which extends axially therethrough. The lower end of the auxiliary bore 192 opens into the opening 142B and the lower end of the auxiliary conductor 182 projects in the same opening. The insulating wall or partition 142C which is formed integrally with the retaining member 142 around the relatively smaller opening 142B through the retaining member 142 assists in preventing certain arc products which may result during the operation of the fuse unit 100 in a relatively smaller opening 142B of the retaining member 142 from being deflected into the relatively larger opening 142A of the retaining member 142 and impinging on parts of the fusible means 160. The retaining member 142 also includes an upwardly projecting tubular portion 142D adjacent to the relatively smaller opening 142B through the retaining member 142 with the projecting portion 142D being joined to the adjacent block 128 around a recess in the block 128 which is adapted to receive the projecting portion 142D by a flexible bonding material, such as silicon rubber. This joint between the retaining member 142 and the block 128 around the auxiliary bore 192 assists in preventing the travel or escape of ionized gases between the auxiliary bore 192 and the main bore 130 and between the auxiliary bore 192 and the relatively larger opening 142 through the retaining member 142 during an interrupting operation of the fuse unit 100.

The elongated conducting member or rod 83 of the refillable unit 20 is normally disposed, as shown in Fig. 2, to extend through the main bore 130 with the upper end of the conducting rod 83 projecting axially beyond the upper end of the casing 110 and with the upper portion of the conducting rod being externally threaded, as indicated at 83A. The conducting rod 83 is normally held in the position shown in Fig. 2 by a connection through the fusible means 160 to the generally annular or tubular lower conducting member or contact 150.

More specifically, the fusible means 160 comprises a strain element 162 and a fusible element or link 164. The upper end of the strain element 162 is secured by suitable means, such as brazing, to the lower end of the conducting rod 83, while the other end of the strain element 162 is secured by suitable means, such as brazing, to the connecting conductor or terminal 156 which is of the flat strip type. The connecting conductor 156 is secured in turn to the lower contact 150 adjacent to the upper end of the lower contact 150 by suitable means, such as brazing. Similarly, the upper end of the fusible element or link 164 is secured to the lower end of the conducting rod 83 by suitable means, such as brazing, while the lower end of the fusible element or link is secured to the lower contact 150 adjacent to the upper end of the lower contact 150 by suitable means, such as brazing. It is to be noted that the strain element 162 and the fusible element 164 are electrically connected in parallel between the lower end of the conducting rod 83 and the lower contact 150 of the renewable unit 20.

Similarly, the auxiliary conductor 182 which is of a relatively smaller cross-section or size than the conducting rod 83 normally extends through the auxiliary bore 192 with the upper end of the auxiliary conductor 182 extending axially beyond the upper end of the auxiliary bore 192 and being both mechanically and

electrically connected to the upper portion of the conducting rod 83 by a transversely extending spring pin 184. The pin 184 is disposed in a transversely extending recess or opening provided at the upper end of the retaining member 189 to prevent rotation of the conducting rod 83 after assembly of the rod 83 in the renewable unit 20. The upper end of the auxiliary conductor 182 may be formed as a loop which is assembled over the conducting spring pin 184 and retained thereon by the head 186 of the spring pin 184. The lower end of the auxiliary conductor 182 extends or projects into the relatively smaller opening 142B of the retaining member 142, as shown in Fig. 2, and is electrically connected through a helical conducting wire of reduced cross-section, as indicated at 194, to an angle-shaped auxiliary stationary terminal 157 which is secured to the tubular conducting member 150 adjacent to the upper end of the member 150 by suitable means, such as brazing. The upper end of the helical wire 194 which is disposed inside the relatively smaller opening 142B of the retaining member 142 is secured to the lower end of the auxiliary conductor 182 by suitable means, such as brazing, and the lower end of the helical wire 194 is secured to the auxiliary terminal 157 by suitable means, such as crimping or brazing.

The lower contact or conducting member 150 also includes an elongated arcing terminal 158, which projects upwarly from the upper end of the contact 150 into the relatively smaller opening 142B of the retaining member 142 to axially overlap the lower end of the auxiliary conducting member 182 with the lower portion of the arcing terminal 158 being disposed adjacent to and generally parallel to the axis of the helical wire 194. The arcing terminal 158 is electrically insulated along its length by a coating or film of electrical insulating material, such as an insulating enamel, which is provided on the arcing terminal 158 to prevent the electrical shorting out of the helical wire 194. The arcing terminal 158 which is formed from an electrically conducting material may be structurally secured to the upper end of the lower contact 150 at the inner periphery thereof by suitable means, such as brazing, or may be formed integrally therewith in a particular application. It is to be noted that the auxiliary current path which extends from the upper portion of the conducting rod 83, through the cross pin 184, the auxiliary conductor 182 and the helical wire 194 to the auxiliary terminal 157 on the lower contact 150 is also electrically connected in parallel with the conducting paths which include, respectively, the strain element 162 and the fusible element 164.

In order to assist in retaining the blocks 122 and 128 and the retaining member 142 in assembled relationship inside the casing 110, as well as for another important purpose during an interrupting operation of the fuse unit 100, the lower tubular conducting member or contact 150 includes a main portion 152 which extends axially inwardly from the lower end of the casing 110 to bear against the lower end of the retaining member 142. The lower contact 150 also includes a flange portion 154 at the lower end thereof against which the lower end of the casing 110 bears when the conducting member 150 is assembled with the casing 110.

In order to retain the lower contact 150, as well as other parts of the renewable unit 20, in assembled relationship with the casing 110 during an interrupting operation of the fuse unit 100, a generally tubular external terminal member or ferrule 172 is disposed to telescope over the lower end of the casing 110. In order to firmly secure the external terminal member 172 to the lower end of the casing 110, the internal surface of the external terminal member 172 and the external surface of the portion of the casing 110 adjacent to the member 172 include adjacent helical grooves which, when the parts are assembled, form a helical passageway in which a helical wire 173 is disposed. In the assembly of the external terminal member 172 on the lower end of the casing 110, the helical wire 173 may be first assembled in the helical groove on the lower end of the casing 110 and the external terminal member 172 may then be screwed onto the lower end of the casing 110 until the parts reach their final positions, as shown in Fig. 2. In order to additionally assist in retaining the external terminal member 172 on the lower end of the casing 110, the outer surface of the casing 110 and the inner surface of the external terminal member 172 may be coated with a cement or bonding material, such as an epoxy bonding material, prior to the assembly of the external terminal member 172 on the lower end of the casing 110. It is to be noted that the external terminal member 172 also includes an inwardly projecting flange portion 172A around a central opening 172B which bears against the adjacent flange portion 154 of the tubular conducting member 150 to assist in retaining the tubular conducting member 150 in assembled relation with the other parts of the renewable unit 20.

In order to form a current conducting path which extends between the lower end fitting 36 and the lower contact 150 of the renewable unit 20, the external terminal member 172 also includes an external flange portion 172C which bears against the inwardly projecting flange portion 36B of the lower end fitting 36. The electrically conducting path thus formed extends from the lower contact 150 through the inwardly projecting flange portion 172A of the external terminal 172 and through the externally projecting flange portion 172C to the inwardly projecting flange portion 36C of the

lower end fitting 36. The area of the current transfer path between the external terminal member 172 of the renewable unit 20 and the lower end fitting 36 may also be augmented by the contact ring 195 which may be formed of electrically conducting material and which is disposed to threadedly engage the internally threaded opening at the lower end of the end fitting 36 and bear against the external terminal member 172 of the renewable unit 20, as shown in Fig. 2.

It is important to note that in order to prevent the concentration of relatively high potential stresses adjacent to the external terminal member 172 during an interrupting operation of the fuse unit 100 at relatively high voltages, the upper end of the lower contact 150 extends axially beyond the upper end of the external terminal member 172 toward the other end of the casing 110 a minimum distance to prevent such a concentration of relatively high potential stresses externally of the casing 100 adjacent to the external terminal member 172.

In order to actuate the axial movement of the conducting rod 83 as well as that of the auxiliary conductor 182 during an interrupting operation of the fuse unit 100 and to electrically connect the renewable or refillable unit 20 just described to the upper end fitting or terminal 34, a spring and cable assembly 30 is disposed inside the outer tube 32 between the renewable unit 20 and the upper end fitting 34. The spring and cable assembly 30 includes at its lower end a generally tubular conducting member or socket 84 having an internally threaded central opening, as indicated at 84A, to receive the upper threaded end 83A of the conducting rod 83. The lower spring seat member 86 is fixedly mounted on the socket 84 for movement therewith by assembling the spring seat 86 over the outer periphery of the socket 84 with the lower end of the spring seat 96 bearing against a shoulder provided on the outer periphery of the socket 84 and with the upper end of the spring seat 86 being engaged by a plurality of portions of the socket 84 at the upper end of the socket 84 which serve to stake or secure the spring seat 86 on the socket 84. The spring and cable assembly 30 also includes an upper spring seat 74 which is slidably disposed over the lower portion 60A of a generally cylindrical conducting member 60 whose integral upper portion 60B extends axially through an opening 34B in the upper end fitting 34 and is externally threaded at the upper end thereof, as indicated at 60C. As illustrated, the generally cylindrical conducting member 60 may be secured to the upper end fitting 34 by an internally threaded end cap 44 which may be screwed down on the upper threaded portion 60C of the conducting member 60 until the flange portion 44A of the end cap 44 bears against the upper end fitting 34 around a flange or shoulder portion, as indicated at 34C in Fig. 2. A helical tension spring 76 is secured at its upper end to the external, helically threaded portion of the upper spring seat 74, while the lower end of the spring 76 is secured to the external, helically threaded portion of the lower spring seat 86 to bias the conducting rod 83, as well as the auxiliary conductor 182, in a generally upward direction, as viewed in Fig. 2, away from the lower contact 150. It is important to note that the turns of the spring 76 are generally rectangular or square in cross-section to substantially prevent any overlapping of the turns 76 and the consequent damage to the spring 76 that might otherwise result during an interrupting operation of the fuse unit 100.

In order to electrically connect the renewable unit 20 and more specifically the conducting rod 83 to the upper end fitting 34 both prior to and during an interrupting operation of the fuse unit 100, a plurality of helically coiled flexible cables or conductors 82 are electrically and structurally connected at the bottom ends thereof to the conducting socket 84 into separate openings (not shown) provided in the socket 84 by suitable means, such as brazing or by staking, and at the upper ends thereof are secured to the conducting member 60 in separate openings provided in the conducting member 60 by suitable means, such as brazing or staking. In order to increase the effective current transfer area between the conducting member 60 and the upper end fitting 34, a washer 54 formed of electrically conducting material may be disposed between the shoulder which is formed at the intersection of the upper and lower portions 60A and 60B, respectively, of the conducting member 60 and the shoulder which is formed inside the upper end fitting 34, as indicated at 34D around the central opening 34B.

In order to facilitate the assembly of the renewable unit 20 and the associated spring and cable assembly 30 inside the outer holder 32 as will be explained hereinafter, a pair of spring pins 58 may be disposed in associated openings provided at the opposite sides of the upper portion 60B of the conducting member 60 to be positioned finally within an enlarged central opening or recess 34E in the upper end fitting 34, as shown in Fig. 2.

In order to actuate the release of the latching assembly 250 shown in Fig. 1 following an interrupting operation by the fuse unit 100, a tripping rod or member 52 is slidably disposed inside a central opening or passageway 72 which is provided in the conducting member 60 with the upper end of the tripping rod 52 being normally positioned below the top of the end cap 44, as shown in Fig. 2. The lower end of the tripping rod 52 is fixedly coupled to the upper spring seat 74 for axial movement therewith by the cross pin 56 which passes laterally through aligned transverse openings in the tripping rod 52 and the upper spring seat 74 and through a pair of elongated

slots 62 provided at the opposite sides of the conducting member 60 with the cross pin 56 being normally positioned at the lower end of the slots 62, as shown in Fig. 2. In order to permit the axial movement of the tripping rod 52 upwardly through the end cap 44 following an interrupting operation of the fuse unit 100, the top of the end cap 44 includes a central opening 46 through which the tripping rod 52 may pass to actuate the release of the latching assembly 250 shown in Fig. 1. When the latching assembly 250 is released by the movement of the tripping rod 52, the upper end of the fuse unit 100 will be actuated to rotate in a clockwise direction, as viewed in Fig. 1, about the lower hinge assembly 260 to thereby provide an electrically insulating gap between the upper break contact 252 and the lower stationary hinge contact 62 by such drop-out action.

In order to assemble the renewable unit 20 and the associated spring and cable assembly 30 into the outer holder 32, the threaded end of the conducting rod 83 is first screwed into the socket 84 at the lower end of the spring and cable assembly 30. A refill fusing tool (not shown) is then screwed into the internally threaded central opening or passageway 72 at the other end of the spring and cable assembly 30. The spring and cable assembly 30 is then inserted into the outer holder 32 with the upper end of the spring and cable assembly 30 being inserted first into the lower end of the outer holder 32, as viewed in Fig. 2, until the refill tool (not shown) passes through the central opening 34B of the upper end fitting 34. By use of the refill tool, the spring 76 is stretched and placed in tension until the cross pins 58 mounted at the sides of the conducting member 60 are drawn upwardly through a pair of radial slots (not shown) provided in the upper end fitting 34 around the central opening 34B. The upper conducting member 60 and the spring and cable assembly 30 are then rotated until the pins 58 rest on the shoulder provided at the bottom of the enlarged opening 34E in the upper end fitting 34. The end cap 44 may then be screwed down on the upper threaded portion 60C of the conducting member 60 to further stretch the spring 76 to the final condition or position shown in Fig. 2 in which the cross pins 58 are drawn upwardly away from the shoulder in the upper end fitting 34 at the bottom of the enlarged opening 34E. It is to be noted that when the spring and cable assembly 30 and the renewable unit 20 are assembled inside the outer holder 32, as just described, the cross pin 56 which couples the upper spring seat 74 to the tripping rod 52 is disposed at the bottom of the slots 62 at the opposite sides of the conducting member 60 to permit limited upward travel of the upper spring seat 74 along with the cross pin 56 and the tripping rod 52 to a final position of the tripping rod 52 in which the tripping rod 52 projects beyond the end cap 44 axially to release the latching assembly 250 as previously mentioned. The washer 54 also acts as a stop surface against which the upper end of the spring seat 74 bears to limit the upward travel of the tripping rod 52, the cross pin 56 and the spring seat 74.

In considering the operation of the fuse unit 100, it is to be noted first that the current paths which include, respectively, the strain element 162, the fusible element 164 and the helical wire 194, which is connected in series with the auxiliary conductor 182, are all electrically connected in parallel between the upper end of the conducting rod 83 and the lower contact 150 at the lower end of the renewable unit 20. The resistance of the current path which includes the fusible element 164 and which is calibrated to have predetermined time-current characteristics is arranged to be relatively much less than the resistance of either the path which includes the strain element 162 or the path which includes the helical wire 194 so that normally most of the current which flows through the fuse unit 100 is carried by the fusible element 164. Although the resistance of the current path which includes the strain element 162 is relatively greater than the resistance of the path which includes the fusible member 164, the resistance of the path which includes the strain element 162 is relatively less than that of the path which includes the helical wire 194 so that when the fusible element 164 melts or blows, most of the current which was formerly carried by the fusible element 164 is then transferred to the strain element 162. In other words, when the current which is flowing through the fuse unit 100 increases to a value which is of sufficient magnitude and duration to melt or blow the fuse element 164, most of the current which is flowing through the fuse unit 100 then transfers to the strain element 162. When the current which is transferred to the strain element 162 after the melting of the fusible element 164 is sufficient to melt or blow the strain element 162, the current which was previously carried by the strain element 162 is finally transferred to the current path through the auxiliary bore 192 which includes the auxiliary conductor 182 and the helical wire 194. No arcing occurs as the elements 162 and 164 melt because of the parallel electrical path through the helical wire 194. When the strain element 162 melts or blows, the conducting rod 83 is no longer restrained from upward movement under the influence of the biasing spring 76 and the conducting rod 83 and the auxiliary conductor 182 will start to move upwardly under the influence of the spring 76 to thereby stretch the helical wire 194 which is electrically connected to the bottom of the auxiliary conductor 182. It is to be noted that the stretching of the helical wire 194 permits limited travel of both the conducting rod 83 and the auxiliary conductor 182

while maintaining a continuous electrical circuit through the auxiliary bore 192 and that as long as the current path which includes the auxiliary conductor 182 and the helical wire 194 is intact, no arcing will take place in either the main bore 130 or in the auxiliary bore 192. In other words, the stretching of the helical wire 194 during the initial movement of the conducting rod 83 and the auxiliary conductor 182 following the melting or blowing of the fusible element 164 and the strain element 162 will permit the formation of an electrically insulating gap in the main bore 130, while initially maintaining a conducting path and delaying the formation of an insulating gap in the auxiliary bore 192.

After the strain element 162 melts or blows as just described, and the conducting rod 83 and the auxiliary conductor 182 begins to move upwardly to thereby stretch the helical wire 194, the helical wire 194 will either fracture mechanically when stretched to its limit or the current transferred to the current path which includes the auxiliary conductor 182 and the helical wire 194 will be sufficient to melt or blow the helical wire 194 which is of reduced cross-section compared with that of the auxiliary conductor or rod 182. After the helical wire 194 is melted or otherwise broken, an arc will be initiated between the retreating end of either the broken helical wire 194 or the auxiliary conductor 182 and the arcing terminal 158 which axially overlaps the lower end of the auxiliary conductor 182 to thereby burn through the electrical insulation on the arcing terminal 158. Even after the wire 194 melts or is broken, the formation of a significant electrically insulating gap in the auxiliary bore 192 is further delayed by the overlapping of the auxiliary conductor 182 by the arcing terminal 158 until the retreating free end of either the wire 194 or the conductor 182 passes the upper end of the arcing terminal 158 whose insulation will have burned through by this time. It is important to note that the insulating gap in the main bore 130 between the separated ends of the conducting parts will increase at a faster rate than the formation of an insulating gap in the auxiliary bore 192 due to both the delay in the formation of an arc in the auxiliary bore 192 because of the presence of the helical wire 194 and due to the overlapping of the auxiliary conductor 182 by the arcing terminal 158. It is also important to note that the arcing which takes place in the fuse unit 100 during an interrupting operation will always take place initially in the auxiliary bore 192, as just explained. When the retreating end of either the helical wire 194 or the auxiliary conductor 182 passes the upper end of the arcing terminal 158, the arcing which takes place initially in the auxiliary bore 192 will cause gases to be evolved from the gas evolving material around the auxiliary bore 192 which will be un-ionized.

When the current to be interrupted by the fuse unit 100 is relatively low, such as 1000 amperes or less, and when the gas pressure of the evolved gases in the auxiliary bore 192 increases to thereby increase the dielectric strength in the auxiliary bore 192, the insulating gap which is formed in the auxiliary bore 192, along with the corresponding increased dielectric strength, will be sufficient to interrupt the alternating current following a particular current zero in the auxiliary bore 192. The insulating gap which is formed simultaneously in the main gap 132 of the fuse unit 100 at a relatively faster rate will have sufficient dielectric strength considering the instantaneous potential difference between the separating conducting parts in the main bore 130 of the fuse unit 100 to prevent a restrike of the arc in the main bore 130 for such relatively low fault currents. In other words, when any fault current is interrupted by the fuse unit 100, as just described, arcing will always be initiated in the auxiliary bore 192 and for relatively small fault currents, the arcing which results will be finally interrupted in the auxiliary bore 192. One important reason for this is that the relative dielectric strength of the main bore 130 at the time that the arc is finally interrupted in the auxiliary bore 192 will be relatively higher than that in the auxiliary bore 192 to prevent a restrike or breakdown of the main bore 130 due to the potential difference which results between the separated conducting parts in the main bore 130.

For relatively higher fault currents, the arcing which is initiated in the fuse unit 100 will still be initiated in the auxiliary bore 192 in the manner just described. For such relatively higher current faults however, the gas pressure which builds up in the auxiliary bore 192 during an interrupting operation and the burning back of the separated conducting parts in the auxiliary bore 192 will result in a relatively higher dielectric strength in the auxiliary bore 192 compared with that in the main bore 130 between the separated conducting parts in the main bore 130. If the instantaneous potential difference between the separated ends of the conducting parts in the main bore 130 is sufficient when the dielectric strength of the main bore 130 becomes relatively less than that of the auxiliary bore 192, the arc will restrike in the main bore 130 to thereby cause the evolution of un-ionized gases in the main bore 130 to thereby increase the gas pressure in the main bore 130, as well as the corresponding dielectric strength in the main bore 130. The arc which restrikes in the main bore 130 will be elongated both by the upward movement of the conducting rod 83 and by the burning back of the separated conducting parts in the main bore to thereby increase the quantity of un-ionized gases evolved from the gas evolving material around the main bore 130. The arc in the main bore 130 will be

finally interrupted following a particular current zero in the alternating current which is being interrupted when the insulating gap and the corresponding dielectric strength in the main bore 130 is sufficient to withstand the instantaneous potential difference between the separated conducting parts in the main bore 130.

If the fault current which is being interrupted by the fuse unit 100 is of a relatively still higher magnitude or value, the gas pressure in the main bore 130 along with the intense heat which results will be sufficient to break up or disintegrate the frangible inner walls 126A and 128A of the blocks 126 and 128, respectively, to thereby limit the gas pressure of evolved gases because of the increase in the size or volume of the gas passageway or volume of the gas space inside the refillable unit 20 to thereby limit the gas pressure of the evolved gases to a value within the rupture strength of the casing 110 as previously explained. It is to be noted that when the inner walls 126A and 128A break up during the operating condition just mentioned, the outer walls of the blocks 126 and 128 will then be exposed to the arc being interrupted and will continue to evolve gases which will aid in arc extinction of the relatively higher currents which result in such an interrupting operation. As mentioned previously, the inner walls 126A and 128A will remain intact when the fuse unit 100 is interrupting relatively lower currents to thereby assist in confining the arc by maintaining a normal size opening of the main bore 130 to more effectively aid in arc extinction.

When the arc is interrupted in the main bore 130 of the fuse unit 100 or in the main bore 130, as enlarged by the breaking up of the inner walls 126A and 128A of the blocks 126 and 128, respectively, as just described to thereby cause the evolution of gas from the gas evolving material in the blocks 122, 124, 126 and 128 which surround the main bore 130, the upward movement of the conducting rod 83 along with the upward movement of the auxiliary conductor 182 will be additionally accelerated by the force of the gas pressure of such evolved gases in the main bore 130 along with the force exerted on the conducting rod 83 by the biasing force of the spring 76.

During an interrupting operation of the fuse unit 100 as just described, when the conducting rod 83 is released and moved upwardly under the influence of the spring 76 or under the influence of both the spring 76 and the gas pressure of the evolved gases inside the renewable unit 20, the turns of the spring 76 which are normally held in tension will partially collapse toward a compressed condition but after the turns of the spring 76 collapse to a certain extent, the upper spring seat 74 will slide axially on the lower portion of the conducting member 60 until the upper end of the spring seat 74 impacts or bears against the washer 54 to thereby drive or actuate the tripping rod 52 in an upward direction as viewed in Fig. 2. The tripping rod 52 will be then actuated from the position shown in Fig. 2 until the upper end of the tripping rod 52 actuates the release of the latching means 250. It is to be noted that the upward movement of the conducting rod 83 and the auxiliary conductor 182 will establish the insulating gap previously described between the separated ends of the conducting parts inside the renewable unit 20 following an interrupting operation. In addition, the fuse unit 100 will be actuated by the release of the latching means 250 by the tripping rod 52 to rotate in a clockwise direction as viewed in Fig. 1 about the lower hinge assembly 260 in a drop-out movement to establish a longer insulating gap between the break contact 252 and the lower stationary hinge contact 262 of the fuse structure 10.

It is important to note that during an interrupting operation of the fuse unit 100 as previously described for either relatively low fault currents or for relatively high currents, the gas seal and joint structure between the successive blocks 122, 124, 126 and 128, as previously described, substantially prevents the escape of ionized gases from the auxiliary bore 192 in which all arcing initially takes place to the main bore 130 along the meeting surfaces of the successive blocks in the renewable unit 20. As previously mentioned, if such ionized gases were permitted to escape to the main bore 130, a restrike might result when the fuse unit 100 is called upon to interrupt relatively low fault currents and the restrike of an arc in the main bore 130 would result in an arcing condition which the fuse unit 100 is incapable of interrupting in the main bore 130 for such relatively low fault currents. This is because for such relatively low fault currents, the quantity of gas evolved in the main bore 130 is not sufficient to establish a dielectric strength in the main bore 130 which would be great enough to interrupt the arc which results for such relatively low fault currents in the main bore 130.

Referring now to Fig. 5, there is illustrated an alternative construction of a fuse unit embodying the invention as indicated at 100^1 in Fig. 5 which includes a modified refillable or renewable unit 20^1 which is structurally the same as the renewable unit 20 previously described except that the renewable unit 20^1 includes a pair of blocks 135 and 137 along with a generally tubular member 133 which are located at the lower end of the body of arc-extinguishing material provided instead of the blocks 126 and 128 which are provided as part of the renewable unit 20. More specifically, as shown in Fig. 5, each of the generally annular blocks of gas evolving, arc-extinguishing material, such as boric acid, includes a rela-

tively large central opening as indicated at 139 for the block 137 in Figs. 6 and 7 and a relatively smaller opening at one side of each of said blocks, as indicated at 141 for the block 137 in Figs. 6 and 7. As best shown in Figs. 6 and 7, each of the blocks 135 and 137 includes a plurality of axially spaced grooves as indicated at 131 for the block 137 which extend around the outer periphery of the associated block with the ends of each groove or recess being spaced from or terminating short of the portion of the associated block which includes the smaller opening of the block, as indicated at 141 for the block 137 in Figs. 6 and 7. The meeting surfaces of the blocks 135 and 137 are structurally joined together with each other and with the surfaces of the associated blocks 122 and 124 by a suitable sealing and bonding material, such as an epoxy bonding material, similarly to the structure of the refillable unit 20 as previously described with the meeting surfaces of the adjacent blocks each including a groove or recess which extends around the smaller opening in the respective blocks, as indicated at 135A for the block 137, the combined passageway which is formed when the grooves in the adjacent blocks are brought together being filled with said bonding material. The latter construction prevents the travel of ionized gases between the main bore of the refillable unit 20^1 and the auxiliary bore as indicated at 192^1 in Fig. 5. It is to be noted that an axially projecting tubular portion remains at the ends of the blocks 135 and 137, as indicated at 137B for the block 137 in Figs. 6 and 7, when the recess or groove is provided around the small opening in the respective block as indicated at 135A for the block 137. The generally tubular member 133 is disposed generally between the blocks 135 and 137 and the associated casing or tube 110 as shown in Fig. 5 with the generally tubular member 133 extending substantially around the outer periphery of the associated blocks 135 and 137 from at least the portions of said blocks which include the relatively smaller openings, as indicated at 141 for the block 137 in Figs. 6 and 7. It is to be noted that a plurality of outwardly extending axially spaced flange portions result in the blocks 135 and 137 because of the presence of the grooves 131, as indicated at 137C, 137D and 137E in Fig. 7 for the block 137. The generally tubular member 133 may include a recess at its lower inner periphery to receive the flange portion 137E of the block 137 which is disposed between the generally tubular member 133 and the lower retaining member 142, as shown in Fig. 5 to assist in retaining the blocks 135 and 137 in assembled relation inside the casing or tube 110. The generally tubular member 133 is preferably formed from a gas evolving, arc-extinguishing material having a greater mechanical strength than the material from which the blocks 135 and 137 is formed, such as a high molecular weight polyoxymethylene which is sold under the trademark "Delrin."

It is to be noted that the meeting ends of the blocks 135 and 137 include central wall portions which meet to close off the grooves or recesses at the outer periphery of the respective blocks, as indicated at 137F for the block 137 in Figs. 6 and 7.

The operation of the fuse unit 100^1 including the modified refillable unit 20^1 is the same as the fuse unit 100 previously described except that for the relatively highest currents to be interrupted by the fuse unit 100^1, the intense heat and gas pressure which result in the main bore 130^1 of the fuse unit 100^1 are sufficient to break up the blocks 135 and 137 which are structurally weakened by the presence of the grooves at the outer periphery as previously described. When the blocks 135 and 137 break up and blow out of the lower end of the refillable unit 20^1, the size of the gas passageway through the main bore 130^1 is suddenly increased or the volume of the gas space is suddenly increased to thereby limit the gas pressure which results during such an interrupting operation to a value lower than that which would otherwise result to thereby limit the gas pressure inside the refillable unit 20^1 to a value within the rupture strength of the casing or tube 110. It is to be noted that when the blocks 135 and 137 break up during the interruption of such relatively high currents, the surface of the generally tubular member 133 is then exposed and will evolve arc-extinguishing gases to aid in arc extinction of such relatively high currents with the generally tubular member 133 remaining in position inside the casing 110 because of its relatively higher strength and resistance to breaking up or disintegration under the influence of the intense heat and gas pressures which result during such an interrupting operation.

It is to be understood that the teachings of the applicant's invention may be applied to power fuses for high voltage applications which are not of the drop-out type It is also to be understood that the teachings of the applicant's invention may be applied to power fuses for high voltage applications which do not include a tubular conducting member or shield, such as the lower contact 150 shown in Fig. 2, but which instead employs a lower contact ring.

The apparatus embodying the teachings of this invention have several advantages. For example, a body of gas evolving arc-extinguishing materials including a plurality of blocks as disclosed with certain of the blocks being structurally weakened to permit the limitation of gas pressure during the interruption of relatively high currents preserves the effectiveness of the arc extinction at relatively lower currents when the gas pressure is not sufficient to cause the breaking up of the weakened

blocks as previously explained. In addition, in at least one embodiment of the applicant's invention the weakened blocks of gas evolving arc-extinguishing material may be formed as unitary members without requiring the assembly of composite layers of gas evolving materials as have been proposed in certain prior art structures. Finally, in a fuse structure as disclosed, the construction of the body of arc-extinguishing material particularly lends itself to a power fuse structure of the dual-bore type since the construction of the blocks as disclosed lends itself to a sealing arrangement which prevents the travel of ionized gases between the main and auxiliary bores as disclosed.

WHAT WE CLAIM IS:—

1. A circuit interrupter comprising a tubular electrically insulating casing, a body of gas evolving, arc-extinguishing material disposed inside of and spaced from the ends of the casing, said body of arc-extinguishing material including a plurality of generally cylindrical blocks stacked axially in end-to-end relation, each of said blocks having a relatively large opening and a relatively small opening extending axially therethrough with the large openings and the small openings, respectively, being substantially aligned, separate conducting means disposed both in the small openings for interruption of first current arcs and in the large openings for interruption of second current arcs said conducting means being connected to separate fusible means disposed inside the casing adjacent to one end of the body of arc-extinguishing material, at least the block adjacent to said fusible means having a recess formed therein spaced laterally from the large opening and extending around the large opening with the ends of the recess being adjacent to and spaced from the small opening, a wall portion of said block surrounding the large opening being sufficiently thin to break under the influence of intense heat and pressure to thereby increase the volume of the large opening through the associated block.

2. A circuit interrupter as claimed in claim 1, wherein the recess is formed in one end face of at least said one and the adjacent block and the ends of the blocks from which the respective recesses extend are disposed to face each other.

3. A circuit interrupter as claimed in claim 1 or 2, wherein the blocks of the body of arc-extinguishing material are cemented to the associated casing by an epoxy bonding material.

4. A circuit interrupter as claimed in claim 1, 2 or 3, wherein each of said recesses extends axially from one end of the respective block to a position which is axially spaced from the other end of the block.

5. A circuit interrupter as claimed in claim 1, wherein a plurality of axially spaced grooves extend around the outer periphery of the block with the ends of each groove being spaced from the smaller opening in the block.

6. A circuit interrupter as claimed in any one of claims 1 to 5, wherein a means is provided for actuating the conducting means to separate upon the fusing of the fusible conducting means.

7. A circuit interrupter as claimed in any one of claims 1 to 6 and substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

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Agent for the Applicants.

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1200707 COMPLETE SPECIFICATION

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Sheet 1

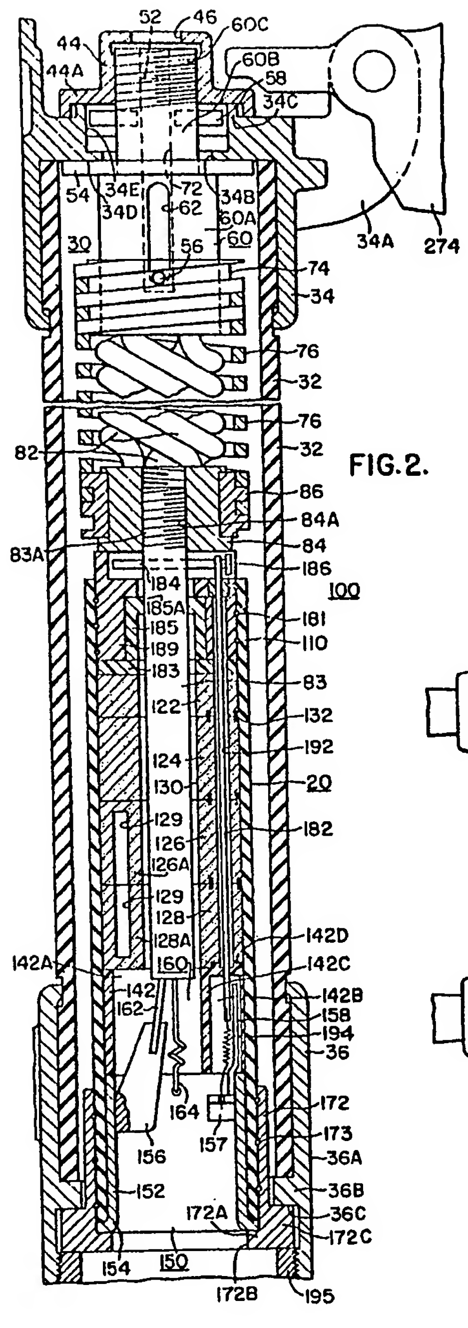
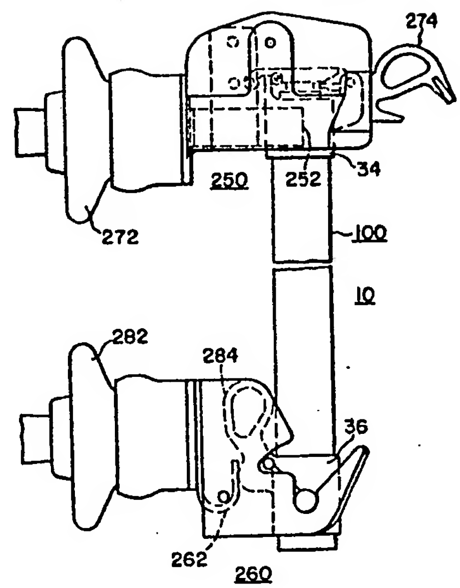


FIG.2.

FIG.1.



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Sheet 2

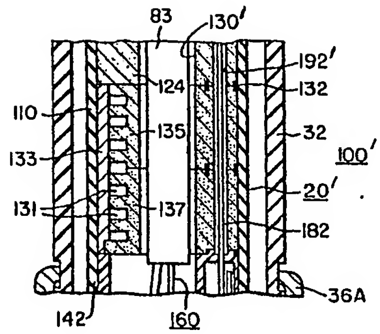


FIG.5.

FIG.3.

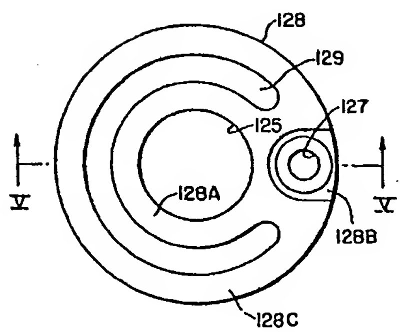
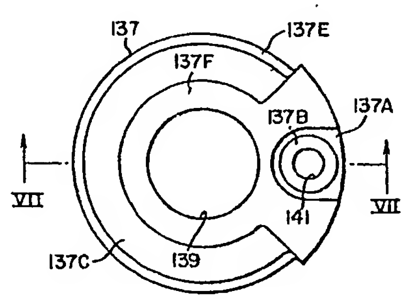


FIG.6.



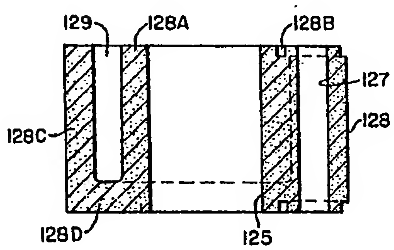


FIG.4.

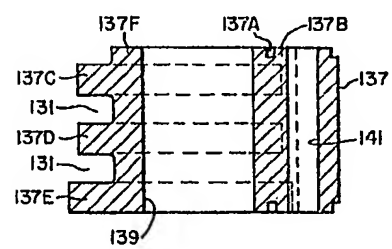


FIG.7.